

## CLAIMS

1. A method of sorting paper, comprising:
- (a) conveying the paper through an inspection zone;
  - 5 (b) analyzing at least the following three characteristics of the paper  
passing through the inspection zone:
    - (1) the color of the paper;
    - (2) whether the paper is glossy; and
    - (3) whether the paper displays printed material; and
  - 10 (c) sorting the paper based upon at least one of the characteristics  
analyzed in step (b).
2. The method of claim 1, further comprising:
- providing a logic map specifying values of parameters corresponding to
  - 15 the three characteristics for a plurality of categories of paper; and
  - wherein step (b) includes determining the parameters for paper of  
unknown category passing through the inspection zone, and comparing the  
parameters for the paper of unknown category to the values in the logic map  
and thereby determining the category of the paper passing through the
  - 20 inspection zone.

3. The method of claim 2, further comprising:

selecting a category of paper to be sorted from the other paper being conveyed through the inspection zone.

5 4. The method of claim 2, wherein:

step (b) includes measuring an intensity of light reflected from the paper and originating from first and second light sources of different colored light.

5. The method of claim 4, wherein:

10 the parameters of the logic map include a log slope of intensities of the reflected light from the first and second sources.

6. The method of claim 4, wherein:

15 the parameters of the logic map include a color derivative representative of a difference in color of adjacent portions of the paper in the inspection zone.

7. The method of claim 4, wherein:

the parameters of the logic map include a combined intensity of the reflected light from the first and second sources.

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8. The method of claim 4, wherein:

the parameters of the logic map include an intensity derivative representative of a difference in the presence of printed matter on adjacent portions of the paper in the inspection zone.

5 9. The method of claim 2, wherein:

the parameters of the logic map include an intensity derivative representative of a difference in the presence of printed matter on adjacent portions of the paper in the inspection zone.

10 10. The method of claim 2, wherein:

step (b) includes measuring an intensity of reflected light reflected from the paper and originating from first and second light sources of the same color light, the first and second light sources being differently oriented so that the measured reflected light from the first source is diffuse reflected light and the  
15 measured reflected light from the second source is directly reflected light.

11. The method of claim 10, wherein:

the parameters of the logic map include a comparison of the diffuse reflected light from the first source with the direct reflected light from the  
20 second source.

12. An apparatus for sorting paper, comprising:
- a conveyor for conveying paper through an inspection zone;
  - a light source for transmitting light onto paper in the inspection zone;
  - a sensor for receiving light reflected from the paper in the inspection
- 5 zone;
- a paper analysis system, operably connected to the sensor for receiving the reflected light signals therefrom, the system including a color determination component, a glossiness determination component, and a printed matter determination component; and
- 10 a sorting mechanism including a select path and a reject path, the sorting mechanism being operably connected to the paper analysis system for sorting paper in response to the analysis conducted by the paper analysis system.
- 15 13. The apparatus of claim 12, wherein the paper analysis system comprises:
- stored data corresponding to predetermined values of parameters corresponding to color, glossiness and the presence of printed matter for a plurality of categories of paper.
- 20 14. The apparatus of claim 13, wherein:

the color determination component, the glossiness determination component, and the printed matter determination component each are constructed to determine parameters for paper of unknown category passing through the inspection zone and compare the parameters of the paper of  
5 unknown category to the stored data.

15. The apparatus of claim 12, further comprising:

a human interface system, including a plurality of pre-defined options for sorting of pre-defined categories of paper, so that a human operator of the  
10 apparatus may select one of the pre-defined options to be implemented by the paper analysis system and the sorting mechanism.

16. The apparatus of claim 15, wherein:

the human interface system includes a sort selection screen having a  
15 single selection associated with each pre-defined option.

17. The apparatus of claim 12, wherein the light source comprises:

a red light emitting diode, a green light emitting diode, and a blue light emitting diode; and  
20 a controller which sequentially flashes the red, green and blue light emitting diodes.

18. The apparatus of claim 17, wherein:

the paper analysis system compares reflected intensities of the red, green and blue lights to determine the color of paper in the inspection zone.

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19. The apparatus of claim 18, wherein:

the paper analysis system includes a color derivative detector for identifying differences in color of adjacent portions of a piece of paper in the inspection zone indicative of the presence of printed matter on the paper.

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20. The apparatus of claim 12, wherein:

the light source includes first and second light emitting diodes of the same color oriented so that the sensor receives diffuse reflected light from the first light emitting diode and directly reflected light from the second light

15 emitting diode; and

the paper analysis system includes a glossiness detector which compares an intensity of the diffuse reflected light to an intensity of the directly reflected light.

20 21. The apparatus of claim 12, wherein:

the paper analysis system includes an intensity derivative detector for identifying differences in intensity of reflected light from adjacent portions of a piece of paper in the inspection zone indicative of the presence of printed matter on the paper.

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22. The apparatus of claim 12, wherein:

the sensor includes a cylindrical bore having an irregular internal surface for deflecting incoming light that is substantially non-parallel to a central axis of the housing.

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23. The apparatus of claim 22, wherein:

the irregular internal surface is threaded.

24. A high speed method of sorting paper, comprising:

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(a) conveying the paper through an inspection zone at a speed of at least 1,000 feet per minute;

(b) analyzing at least one characteristic of the paper passing through the inspection zone, the at least one characteristic being selected from the group consisting of color, glossiness and the presence of printed matter; and

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(c) sorting the paper downstream of the inspection zone based upon the analysis of step (b).

25. The method of claim 24, wherein the speed in step (a) is at least 1,500 feet per minute.

5 26. The method of claim 24, further comprising:

exposing the paper in the inspection zone to a plurality of separate sources of visible light of different wavelengths;

wherein step (b) includes analyzing the color of the paper based upon a comparison of the paper's reflectivity of the different wavelengths of visible

10 light; and

wherein step (c) includes sorting the paper based upon the color of the paper.

27. The method of claim 26, wherein:

15 step (b) includes analyzing whether the paper is glossy; and

step (c) includes sorting the paper depending upon whether the paper is glossy.

28. The method of claim 26, wherein:

20 step (b) includes analyzing whether the paper has a printed surface; and



step (c) includes sorting the paper based upon whether the paper has a printed surface.

29. The method of claim 24, further comprising:

5 collecting diffuse reflected light reflected off the paper from a first light source;

collecting dielectric reflected light reflected off the paper from a second light source;

wherein step (b) includes analyzing the glossiness of the paper based upon a comparison of the diffuse reflected light to the dielectric reflected light;  
10 and

wherein step (c) includes sorting the paper based upon the glossiness of the paper.

15 30. The method of claim 24, further comprising:

comparing intensities of the light reflected from adjacent pixels of the paper within the inspection zone to identify paper with a varying reflectance from adjacent pixels resulting from the presence of printed matter on the paper;  
and

20 wherein step (c) includes sorting the paper based upon the presence of printed matter on the paper.

31. A method of sorting paper, comprising:

- (a) moving the paper through an inspection zone;
- (b) exposing the paper in the inspection zone to a plurality of separate  
5 beams of visible light of different wavelengths;
- (c) analyzing a color of the paper based upon a comparison of the  
paper's reflectivity of the different wavelengths of visible light; and
- (d) sorting the paper downstream of the inspection zone based upon  
the color of the paper.

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32. The method of claim 31, wherein:

in step (b), the plurality of separate beams of visible light include a red  
light, a blue light and a green light.

15 33. The method of claim 32, wherein:

the red, green and blue lights are emitted from red, green and blue light  
emitting diodes.

34. The method of claim 32, wherein:

20 step (c) includes computing log slopes based upon ratios of the logs of the  
reflectivity of the different colored lights.

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37. The method of claim 32, wherein:

38. The method of claim 31, wherein:

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sequence, so that two reflected light signals are generated for each wavelength of light; and

step (c) includes combining the analysis of the two reflected light signals for each wavelength of light to correct for dynamic aberration of the sensed  
5 color of the paper moving within the inspection zone.

39. The method of claim 38, wherein:

the combined analysis in step (c) includes averaging the two reflected light signals.

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40. The method of claim 38, wherein:

step (b) includes an interval of no exposure from any of the separate beams of visible light between the first and second sequences.

15 41. The method of claim 38, wherein:

the plurality of separate beams of visible light of different wavelengths includes a red light, a green light and a blue light.

42. The method of claim 41, wherein:

20 step (b) further includes exposing the paper in the inspection zone to infrared light.

43. A method of analyzing a color of a moving object, comprising:

- (a) moving an object within an inspection zone;
- (b) sequentially interrogating the inspection zone with multiple light sources of different light wavelengths as the object moves within the inspection zone, the interrogation including a first series of sequential flashes of the multiple light sources in a first order, followed by a second series of sequential flashes of the multiple light sources in a second order which is the inverse of the first order; and
- (c) analyzing reflections of the multiple light sources from the paper, the analyzing including consideration of two reflections originating from each light source, one of the two reflections occurring during the first series and the other of the two reflections occurring during the second series.

44. The method of claim 43, wherein:

the consideration of two reflections in step (c) includes averaging the two reflections.

45. The method of claim 43, wherein:

- step (b) includes an interval of no light flashes from any of the multiple sources between the first and second series.

46. The method of claim 43, wherein:

the multiple light sources used in step (b) include a source of red light, a source of green light, and a source of blue light.

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47. The method of claim 46, wherein:

the multiple light sources used in step (b) further includes a source of infrared light.

10 48. The method of claim 43, wherein:

the consideration of two reflections originating from each light source in step (c) corrects for dynamic aberration of the sensed color of the object moving within the inspection zone and thereby approximates a true color of the object.

15 49. The method of claim 43, wherein:

in step (b) the first and second series of sequential flashes are performed during an interrogation time interval less than a time required for a pixel of an object equal in size to the inspection zone to move through the inspection zone.

20 50. The method of claim 43, wherein the object is a piece of paper in a stream of waste paper.

51. The method of claim 50, wherein:

step (a) includes moving the stream of waste paper through the inspection zone at a speed in excess of 1,000 feet per minute.

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52. The method of claim 51, wherein the speed is in excess of 1,500 feet per minute.

53. A paper sorting apparatus, comprising:

10 a conveyor for conveying paper through an inspection zone, the conveyor having a width;

a light transmitter for transmitting light onto paper in the inspection zone, the light transmitter including an array of red lights, an array of green lights and an array of blue lights, each array being spaced across the width of  
15 the conveyor; and

a light receiver for receiving light reflected from paper in the inspection zone, the light receiver including an array of sensors spaced across the width of the conveyor, each sensor receiving light reflected from an area defining one pixel of the paper.

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54. The apparatus of claim 53, further comprising:

a control system for flashing the red, green and blue lights in a first sequence and then in second sequence which is the reverse of the first sequence; and

an analysis system for analyzing both the first and second sequence  
5 reflections of each of the red, green and blue lights from each pixel of the paper to approximate the true color of that pixel.

55. The apparatus of claim 53, wherein:

the light transmitter and the light receiver are both located above the  
10 conveyor.

56. The apparatus of claim 55, further comprising:

a mirror arranged so that the light from the transmitter reflects off of the mirror onto the inspection zone, and the light reflected from paper in the  
15 inspection zone reflects off of the mirror into the light receiver.

57. The apparatus of claim 56, further comprising:

a reference surface located above the transmitter;  
wherein the mirror is pivoted so that it can move between an operating  
20 position in which the light from the transmitter is reflected onto the inspection



zone, and a normalization position in which light from the transmitter is reflected onto the reference surface.

58. The apparatus of claim 57, further comprising:

- 5 a transparent wear cover located between the mirror and the conveyor;  
and  
a reference wear cover located between the mirror and the reference surface.

10 59. The apparatus of claim 53, further comprising:

- a control system for flashing the red, green and blue lights in a sequence;  
and  
an analysis system for analyzing the reflections of each of the red, green and blue lights from each pixel of the paper to determine a color of that pixel.

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60. The apparatus of claim 59, wherein:

- the analysis system includes a means for comparing the intensities of reflected red, green and blue light from each pixel.

20 61. The apparatus of claim 60, wherein:

the analysis systems includes a means for computing a combined  
intensity of the reflected red, green and blue light from each pixel.

62. The apparatus of claim 61, wherein:

5 the analysis system includes a means for computing a difference in  
combined intensity for adjacent pixels to identify the presence of printed matter  
on the paper.

63. The apparatus of claim 60, wherein:

10 the analysis system includes a means for identifying a color difference  
between adjacent pixels to identify the presence of printed matter on the paper.

64. The apparatus of claim 53, wherein:

15 the sensor includes a cylindrical housing having an irregular internal  
surface for deflecting incoming light that is substantially non-parallel to a  
central axis of the housing.

65. The apparatus of claim 64, wherein:

the irregular internal surface is threaded.

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66. A method of sorting paper, comprising:

- (a) moving the paper through an inspection zone;
  - (b) transmitting light onto the paper in the inspection zone;
  - (c) collecting light reflected from the paper;
  - (d) comparing parameters of the light collected from adjacent portions
- 5 of the paper within the inspection zone to identify paper with a varying reflectance from adjacent portions resulting from a presence of printed matter on the paper; and

(e) sorting the paper based upon the presence of printed matter on the paper.

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67. The method of claim 66, wherein:

step (d) includes comparing an intensity of light reflected from the adjacent portions of the paper.

15 68. The method of claim 66, wherein:

step (d) includes identifying differences in color of the adjacent portions of the paper.

69. A method of sorting paper, comprising:

- 20
- (a) moving the paper through an inspection zone;
  - (b) transmitting a first light beam from a first source onto the paper;

(c) receiving a diffuse reflected first light beam, reflected from the paper as a result of the first light beam;

(d) transmitting a second light beam from a second source onto the paper;

5 (e) receiving a directly reflected second light beam, reflected from the paper as a result of the second light beam;

(f) analyzing a glossiness of the paper based upon a comparison of the diffuse reflected first light beam to the directly reflected second light beam; and

10 (g) sorting the paper based upon the glossiness of the paper.

70. The method of claim 69, wherein:

the first and second light beams of steps (b) and (d) are light beams of the same wavelengths.

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71. The method of claim 70, wherein:

the first and second light beams are both infrared light.

72. The method of claim 70, wherein:

20 the second source is a diffuse source so that glossiness of crumpled paper can be detected.

73. The method of claim 69, wherein:

the first and second light beams in steps (b) and (d) are transmitted at opposite angles on opposite sides of a plane normal to a direction in which the paper is moving.

74. The method of claim 69, wherein:

steps (b) and (c) occur prior to steps (d) and (e).

75. The method of claim 69, wherein:

steps (d) and (e) occur prior to steps (b) and (c).

76. The method of claim 69, wherein:

step (f) includes comparing an intensity of the diffuse reflected first light beam to an intensity of the direct reflected second light beam; and determining that the paper is not glossy if the intensities are substantially equal.

77. An apparatus for sorting paper, based on glossiness comprising:

a conveyor for conveying paper through an inspection zone;

first and second light sources for transmitting light onto the inspection zone;

- a sensor for receiving light reflected from the inspection zone;
- the first light source is oriented so that the sensor receives diffuse reflected light from the first light source; and
- the second light source is oriented so that the sensor receives directly reflected light from the second light source.

78. The apparatus of claim 77, wherein:

the first and second light sources transmit the same color of light.

79. The apparatus of claim 78, wherein the light is infrared.

80. The apparatus of claim 78, wherein the first and second light sources are light emitting diodes.

81. The apparatus of claim 77, wherein:

the first and second light sources are located on opposite sides of an imaginary plane normal to the direction of conveyance of the paper and passing through the inspection zone.

82. The apparatus of claim 81, further comprising:

the first light source being oriented in a direction parallel to the direction  
of conveyance of the paper;

a mirror oriented to reflect light from the first light source onto the  
inspection zone; and

5 the second light source is oriented to direct light from the second light  
source directly onto the inspection zone.

83. The apparatus of claim 82, wherein:

the second light source is a wide diffuse light source to accommodate  
10 detection of glossy paper which is not lying exactly flat upon the conveyor.

84. A method of sorting paper, comprising:

(a) conveying paper through an inspection zone;  
(b) transmitting light from an array of light sources onto a mirror;  
15 (c) reflecting light from the mirror onto the inspection zone and off  
paper in the inspection zone back to the mirror;

(d) receiving light from the mirror in an array of sensors which  
sensors generate signals corresponding to characteristics of the paper in the  
inspection zone;

(e) moving the mirror to a normalization position wherein light from the array of light sources is reflected from the mirror onto a reference surface; and

(f) normalizing outputs from the array of sensors with reference to  
5 light reflected off the reference surface.

85. The method of claim 84, wherein:

in step (c), light passing between the mirror and the inspection zone passes through a transparent wear cover; and

10 when the mirror is in the normalization position, light passing between the mirror and the reference surface passes through a reference wear cover of light transmissive properties equal to those of the transparent wear cover.

86. The method of claim 84, wherein:

15 steps (e) and (f) are automatically performed on a periodic basis.

87. The method of claim 84, wherein:

steps (e) and (f) are performed upon startup of the method.



88. The method of claim 84, wherein:
- in step (a), the paper is conveyed on a black conveyor belt; and
- in step (e), the reference surface is white.